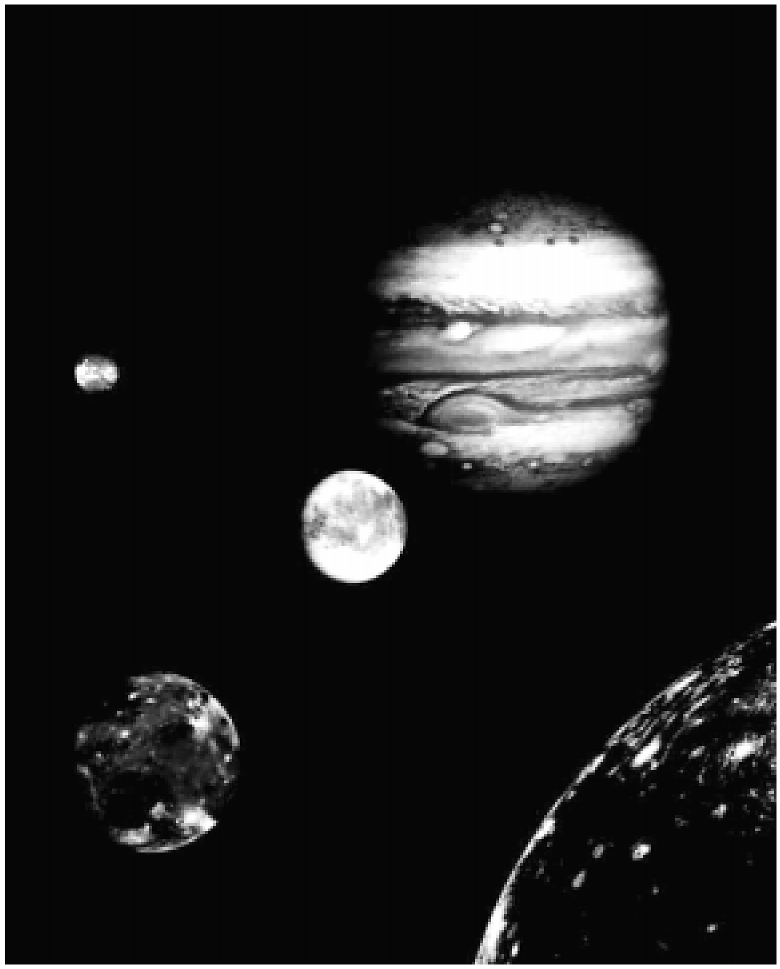
Beyond cutting edge

NASA-sponsored group searches for ways to revolutionize space travel



By Susan Walsh

Warp drives . . .hyperspace . . . tachyons . . . wormholes . . . space drives . . . If you believe that no one but science fiction buffs use these terms, *think again*.

A loosely formed and expanding group of more than 150 scientists and engineers from NASA, other government labs, universities and industries are looking for ways to make "credible progress toward incredible possibilities" in space propulsion. The ultimate goal is to revolutionize space travel and enable practical interstellar voyages.

It's the kind of stuff that, even if only partially successful, would add new chapters to the laws of physics as we know it and potentially make space as navigable as Earth's visible sky is by airplane.

The Breakthrough Propulsion Physics Program established in 1996 is managed by Lewis Research Center (LeRC) in Cleveland, Ohio, and receives funding from the Advanced Space Transportation Program under NASA's Marshall Space Flight Center, where some related experiments are being conducted. The program's sole full-time employee is LeRC aerospace engineer Marc Millis, who was a KSC co-op student from Georgia Tech in 1978-81.

"This is the most visionary thing going on in propulsion in NASA," Millis said. "This is looking at the emerging horizons. You're beginning to get a glimmer of light there. There's some hope that you can do this, but it's still far enough away that you can't be sure. There is, however, enough light to point to where to look next — the next steps."

The program's first workshop held at LeRC in August was to assess the prospect of discovering breakthrough means to propel spacecraft as far and as fast as possible with the least amount of effort. The 84 participants were encouraged to be "visionary" and yet identify affordable, near-term and credible research to make measurable progress toward propulsion breakthroughs.

"Admittedly, these breakthroughs may turn out to be impossible, but progress is not made by conceding defeat," Millis stated in a summary of preliminary workshop results.

Rocket technology dependent on propellant is adequate for human journeys into orbit, to the Moon, and to Mars, and for robotic probes to outer planets of our solar system.

"However, to dramatically reduce the expense of these journeys or to journey beyond these points in a reasonable time, some new, alternative propulsion physics is required," according to Millis.

Conference attendees looked at ways to make interstellar travel practical by removal of the three major barriers to such journeys: propellant mass, trip time, and propulsion energy.

In his essay, *Warp Drive, When?*, Millis said that the obvious challenge in interstellar travel, especially by humans, is speed. The next nearest star is 4.3 light years away. (A light year is the distance that light travels in one year or about 5.88 trillion miles.)

Consider traveling from Earth to that distant star in these known modes of transportation:

• A car traveling at 55 mph would take more than 50 million years to get there!

• At the speed of the Apollo spacecraft which landed on the Moon, it would take over 900,000 years!

• Even at the now-staggering 37,000 mph speed of NASA's voyager spacecraft as it left our solar system, the trip to the nearest star would still take 80,000 years!

That's why the Breakthrough Propulsion Physics Program is looking at recent theories about "wormholes" and "warp drives" — concepts for traveling faster than light.

As for the amount of propellant it would take to get there, you can forget using the chemical engines now on the Space Shuttle — there isn't enough mass in the universe to supply the necessary amount of rocket propellant.

Even with a fission rocket, it would take a billion super-tanker-sized propellant tanks; with fusion rockets, a paltry thousand supertankers worth! That's why the group is searching for new propulsion physics that do not require any propellant.

Even if we could convert energy into motion without propellant, sending a Shuttle-sized vehicle to the nearest star would require roughly the same amount of energy that the Space Shuttle's engines would use if they ran continuously for 50 years.

Tapping the energy stored within the vacuum of space is one idea being explored to overcome this hurdle to interstellar travel.

Millis readily admitted that he doesn't know when a breakthrough will occur, or if it is even possible.

"Even if it will not be in my lifetime or my children's lifetime or even if it is impossible, I am firmly convinced that we as a society will gain far more from trying to make such breakthroughs happen than if we didn't," he asserted in *Warp Drive, When?*, calling it a "noble and honorable cause."

For more information on the Breakthrough Propulsion Physics Program, see URL: http://www.lerc.nasa.gov/WWW/bpp/

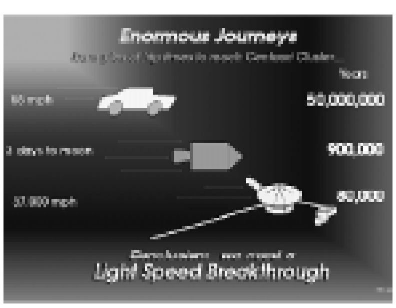


CHART from the Breakthrough Propulsion Physics Program managed by NASA's Lewis Research Center illustrates the need for a major paradigm shift in how we look at spacecraft speed and what is needed for future flights.

NASA's X-38 technology demonstrator for the Crew Return Vehicle could become the first new human spacecraft to travel to and from orbit in the past two decades. It is shown here undergoing captive-carry flight tests in California in July, attached to the wing of a B-52 carrier aircraft. The captive-carry flights will lead up to free-flight drop tests and eventually an unpiloted space flight test targeted for launch aboard a Space Shuttle. The effort, managed by Johnson Space Center, takes advantage of available equipment and technology for as much as 80 percent of the X-38's design in order to keep costs to a minimum.

Launch vehicles of future taking shape today

NASA, the Department of Defense and private industry are working on development of near-term and longer-range future expendable launch vehicles (ELVs) and reusable launch vehicles (RLVs).

The space agency is evolving into a developer of technology, and away from designing, building and owning launcher systems, according to Gary Payton, NASA's RLV program director.

"New commercial launchers will will be built out of the proven technologies," he said.

Among the highlights in the ELV category:

• **Sea Launch:** A two-stage Ukrainian Zenit rocket with a Russian Block DM upper stage will launch from a mobile, modified self-propelled oil drilling platform in the Pacific Ocean into either geosynchronous or medium Earth orbit. Up to 11,025 pounds of payload can be launched to geostationary transfer orbit. The Sea Launch home port in Long Beach, Calif., will include docking and provisioning for the Assembly and Command Ship and Launch Platform; launch will take place along the equator in the international waters of the Pacific Ocean. The first launch is targeted for late 1998.

• **DoD Evolved Expendable Launch Vehicle:** The Air Force has selected two contractors, The Boeing Co. and Lockheed Martin Astronautics, to proceed with the pre-engineering, manufacturing and development (Module II) phase for a new family of expendable rockets to replace the current medium- and heavy-rocket fleet of aging Delta, Atlas and Titan vehicles. The first test flight is targeted to occur in 2001.

• **Lockheed Martin Atlas IIAR:** The new Atlas IIAR vehicle is the latest configuration in Lockheed Martin's planned evolution to a new family of lower-cost ELVs featuring common elements such as a booster stage. The Atlas IIAR can deliver a payload of 8,600 pounds into geosynchronous transfer orbit, approximately an 8 percent increase over the current Atlas IIAS. The first launch is scheduled at the end of 1998.

• **Magnum Launch Vehicle:** Still only a design concept at this time, the Shuttle-derived Magnum would be a heavy-lift vehicle with a payload capacity of some 80 metric tons, more than four times what the Space Shuttle can carry to low Earth orbit. It likely would use a stretched version of the Shuttle's external tank and reusable, liquid-fueled flyback boosters being considered for development in the Space Shuttle program. Potential uses are for human exploration of the Moon and Mars; to carry the next-generation space telescope; in the Air Force space-based laser program; and even, possibly, for interception if an asteroid were hurtling toward Earth.

Some highlights in the RLV category:

• **X-33 and X-34:** The X-34 demonstrator vehicle is a bridge between the Delta Clipper and the X-33. White Sands Missile Range, N.M., will host the initial test flights to prove the major vehicle components, beginning in late 1998. With a current plan to fly a total of about 25 flights, KSC will provide landing support for the other opportunities.

The X-33, being developed under a cooperative agreement between NASA and Lockheed Martin Skunk Works, is a subscale technology prototype which Lockheed hopes to develop in the next century as a full-scale, commercial single-stage-to-orbit reusable launch vehicle called Venture Star™.

• **X-38:** The X-38 is a technology demonstrator for NASA's emergency crew return vehicle (CRV), a lifeboat for the International Space Station. The first captive-carry flights were held at Dryden Flight Research Center in California this summer.

The X-38 would glide from orbit unpowered like the Shuttle orbiter and use a steerable parafoil parachute for its final descent to landing. It also could be used as a spacecraft for humans that could be launched on an Ariane 5 booster.

Upgrades will keep fleet operational until year 2030

By Joel Wells

The Space Shuttle is America's only means of getting humans into space. With the International Space Station (ISS) era around the corner, it will be the workhorse that helps assemble and maintain the permanent space outpost. With NASA counting on the Shuttle, the Shuttle program is counting up ways to keep it flying.

In April 1996, NASA launched a four-phased mission to assure safe and continuous operation of the Shuttle fleet through the year 2012 and to incorporate major improvements through 2030. Improving Shuttle safety, supporting the future flight manifest, increasing system reliability and reducing operational cost are the priorities of the Space Shuttle Upgrade Program.

4 phases

Phase One leads the way, focusing on performance enhancements which extend the Shuttle's capability to carry payloads to the ISS orbital inclination of 51.6 degrees and altitude of about 220 miles. The super lightweight external tank (SLWT) made of a new, aluminum-lithium alloy and the Block II Space Shuttle main engines with new safety features and a higher thrust rating are among the fully funded projects that will help accomplish the goals of Phase One by the year 2000.

High-value upgrades that can be implemented at low cost and still provide reliable support to the current flight manifest define the Phase Two projects. The Checkout and Launch Control System (CLCS), now under development at KSC, is a Phase Two effort to reduce launch processing time while lowering operations costs by 50 percent.

By 2000, many of the upgrades from Phases One and Two will be in place and implementation of the major system upgrades will begin. These Phase Three improvements will be more extensive than their predecessors. The changes would not alter the orbiter's original shape or basic aerodynamics, but would include significant enhancements to avionics and communication systems.

15 flights per year

With a goal to increase the Shuttle's missions per year by 2007, NASA must reduce the preparation time for a launch. By replacing the current orbital maneuvering system, reaction control system and auxiliary power units with systems that do not require toxic propellants or reactants, a safer work place can be achieved and significant time savings can be realized.

Using non-toxic liquid oxygen and ethanol instead of noxious ammonia-based fluids will allow work to be done in parallel with traditionally hazardous operations. Increased productivity, fewer components and cheaper propellants promise a savings of about $24 million every year.

Candidate projects for Phase Four will significantly change the Shuttle's configuration, and new design implementation will be carefully planned to minimize any impact to the flight rate.

A banner project being studied for Phase Four implementation is the liquid fly-back booster (LFBB). The new boosters will not only shorten turnaround time, but are expected to demonstrate key safety features as well.

A CAREFULLY planned and implemented program of upgrades will keep the fleet of four Shuttle orbiters flying well into the next century, possibly as far into the future as 2030. The program began in 1996 and includes four phases. Shown here is the orbiter Columbia undergoing lifting in the Vehicle Assembly Building in October in preparation for Mission STS-87, the final Shuttle flight of 1997. Projections call for an increased flight rate of up to 15 per year in the next century, and many of the planned upgrades will contribute to a reduced turnaround time as well as greater safety and lower costs.

New Shuttle health monitoring system anticipates future demands

NASA's Shuttle Upgrades Program plans to outfit each Shuttle in the fleet with an Integrated Vehicle Health Monitoring System (IVHM), consisting of modern technology that will reduce planned ground processing work, streamline unplanned work, enhance visibility into orbiter systems operation and ultimately improve vehicle safety.

The current onboard Modular Auxiliary Data System (MADS) collects and records pressure, temperature, strain, vibration and event data from sensors placed throughout the orbiter. The information is gathered during ascent, orbit and entry and recorded for postflight review. While effective, MADS requires labor-intensive manual processing.

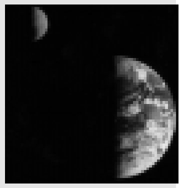
"This is a high-priority project," said Jack Fox, project development manager for KSC's Shuttle Upgrades Office. "When I see plans to increase the Shuttle's flight rate to 15 flights per year, I know we need IVHM to help reduce turnaround time."

The goal is not to scrap the proven MADS system, but rather absorb and improve it. Adding non-intrusive microsensors, strategically placed remote health nodes, and reducing the amount of wiring required, are all steps toward gradual IVHM implementation.

Beyond merely recording flight data, the evolved system will process the information in-flight and dump the data to ground controllers once a day. Onboard trend analysis will give engineers snapshots to help predict downstream maintenance, and improved ground support equipment will help Shuttle technicians do their jobs quicker. KSC managers estimate a fully operational IVHM system will reduce work shifts for orbiter processing by up to 20 percent.

"For example, Marshall Space Flight Center currently waits up to four weeks after a Shuttle lands to receive its engine data from KSC," adds Fox. "Through IVHM, earlier access would give it a jump on planning the processing flow for the Shuttle's main engines." IVHM hardware installation is slated to begin in late 1999.

2004: Deadline for Mars vs. moon decision



It's 2004 and final decision time for NASA. Should the agency press on to finalize plans for the human exploration of Mars? Or should the moon be used first to field-test habitats, life support systems and propellant propulsion units developed for the Mars mission?

And ultimately, does all of the information gathered by robotic Mars explorers and NASA research personnel and mission planners prove that humans really could be safely sent to explore the Red Planet and return? Of course, any of these options would be contingent upon presidential and congressional approval, as well as public support. "It is the job of the KSC Exploration Think Tank to help provide the agency with enough information to make a rational go/no-go decision in 2004 if we are going to launch a crew to Mars by 2013," said Think Tank manager Mike O'Neal. "To do so, we are working to determine how KSC expertise and resources can be used to develop the technologies necessary to demonstrate the Mars mission concept."

Fuel . . .

(Continued from Page 4)

Mars Reference Mission. Once transported from Earth to Mars, the unit will use liquid hydrogen brought from home and carbon dioxide from the Martian atmosphere to manufacture tons of liquid oxygen and methane for the Mars Ascent Vehicle which will lift the crew off the surface to begin the return to Earth. Because propellants make up the majority of a launch vehicle's weight, propellant production on Mars greatly reduces the size and cost of the vehicles required to get there.

"The liquid hydrogen to be used by the ISPP as well as the liquid oxygen to be produced on Mars calls for experience in the handling, transfer and long-term storage of cryogenic liquids," Johnson said. "We have a lot of experience at KSC in doing just that, and we want to apply that knowledge to help design and test the Mars cryogenic systems to assure that they operate as efficiently and reliably as possible with minimum human involvement from Earth."

To provide an autonomous system to monitor the ISPP and to control fuel production and its loading aboard the Mars Ascent Vehicle, the Exploration Team has proposed the use of the KSC-developed Knowledge-based Autonomous Test Engineer (KATE), Johnson said.

"The KATE system can provide the kind of autonomous control that will be required for ISPP operations," Johnson said.

Preventive failure analysis can also be provided for the ISPP design by the KSC Materials Science Laboratory, Johnson said. The lab is planning to build a large environmental chamber that will simulate conditions on the surface of Mars.

In spite of the futuristic purpose of the ISPP, its design for the most part does not call for new technologies or the development of new chemical processes, Johnson said. "What it does call for are the knowledge and experience that can lead to the development of an efficient, reduced-weight and reliable system that is critical to the success of NASA's human exploration of Mars."

Food . . .

(Continued from Page 4)

NASA Mars Reference Mission calls for a six-member crew to remain on the surface of Mars for up to 600 days."

Sager is an advocate of the primarily bioregenerative approach to NASA's Advanced Life Support (ALS) Program as opposed to a more traditional one of mostly chemical and mechanical systems for several reasons.

"Bioregenerative systems are efficient ways to provide all life support elements — oxygen, water and food — as well as a livable psychological environment for the crew over a long period of time," Sager said.

White globe radish harvest

"KSC's job is to obtain sufficient ALS data for the agency to make an informed decision about how much of the life support system on Mars will be bioregenerative," Sager said.

The bioregenerative life support effort at KSC, formerly the Controlled Ecological Life Support System (CELSS) Breadboard Project, is located in Hangar L on Cape Canaveral Air Station.

The KSC-developed bioregenerative hardware and data from the successful growth of soybean, potato, wheat, lettuce and tomato crops are now supporting closed-chamber testing of an ALS regenerative life support systems with human subjects at Johnson Space Center. The latest phase of the Lunar-Mars Life Support Test Project at JSC began Sept. 17.

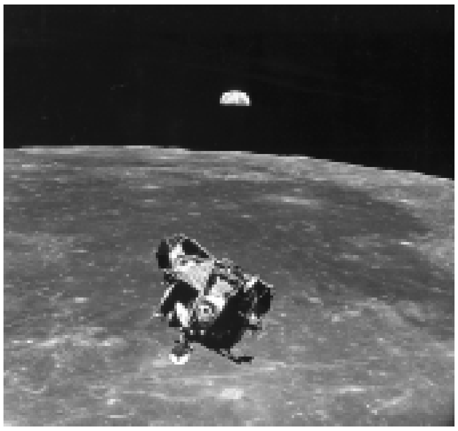
"Data from experiments up to more than a year long have shown that potato and wheat crops grown in the 20-square-meter KSC Biomass Production Chamber could provide all of the water needs for four or five crew members while also meeting the oxygen supply and carbon dioxide removal needs of one person," said Gary Stutte, a plant physiologist with the NASA Life Sciences support contractor Dynamac Co. "The crop could also supply 35 to 50 percent of the food requirements for one person."

Research in the KSC growth chamber is now concentrating on the recycling of inedible plant material — the plant stems, root systems and leaves — from the harvested crops for use in the plant growth chamber.

Work at KSC will continue to support human-rated ALS testing at JSC, the growth of new crops, and further development of the bioreactor, nutrient delivery and lighting systems, Sager said.

"Reliable regenerative life support systems will reduce the amount of materials that need to be sent from Earth to Mars and use less power than currently available life support systems," Sager said. "They are an integral element of NASA's Human Exploration and Development of Space effort and essential to the successful human exploration and colonization of space."

PLANT researchers examine a harvest of lettuce from the KSC Biomass Production Chamber. Wheat, potatoes, soybeans and tomatoes also have been harvested.



Apollo 11

U.S. space exploration yesterday, today and tomorrow

Explorer I

1950s

Jan. 31, 1958. Explorer I, first U.S. satellite.*

October 1958. National Advisory Committee Agency (NACA) becomes National Aeronautics and Space Administration (NASA).

Aug. 7, 1959. Explorer 6, Thor-Able. Returned first television images of Earth from space.

Alan Shepard

1960s

April 1, 1960, Tiros 1, Thor-Able-5. First weather satellite.

May 5, 1961. Freedom 7, Mercury-Restone 3. Alan Shepard become first American to fly in suborbital space.

Feb. 20, 1962. Friendship 7, Mercury-Atlas 6. John Glenn. First manned U.S. orbital flight.

July 10, 1962. Telstar 1, Delta-11. First commercial communications satellite.

Aug. 27, 1962. Mariner 2, Atlas-Agena-6. First U.S. interplanetary probe to reach Venus.

Aug. 22, 1963. X-15 aircraft achieves altitude record of 354,200 feet (67 miles).

July 28, 1964. Ranger 7, Atlas-Agena-9. First U.S. spacecraft to impact on the moon.

June 3-7, 1965. Gemini-Titan 4. Edward White becomes first American to walk in space.

May 15, 1966. Nimbus 2, Thor-Agena D. Produced satellite pictures that became popular feature on television evening news.

May 30, 1966. Surveyor 1, Atlas-Centaur-20. First U.S. spacecraft to soft-land on the moon (in the Ocean of Storms area).

Jan. 27, 1967. Apollo 1 ground test fire takes lives of astronauts Grissom, Chaffee and White.

Dec. 21-27, 1968. Apollo 8, Saturn V. Borman, Lovell, Anders. First manned flight to the Moon.

July 16-24, 1969. Apollo 11, Saturn V. Armstrong, Aldrin, Collins. First humans to set foot on another celestial body, Earth's moon, July 20.

1970s

March 2, 1972. Pioneer 10. Atlas-Centaur-27. First spacecraft to explore beyond Pluto, first man-made object to leave the solar system.

July 23, 1972. LANDSAT 1, Delta-89. First satellite to perform major assessment of Earth resources from outer space.

Dec. 7-19, 1972. Saturn V/Apollo 17. Cernan, Evans, Schmitt. Final Apollo mission; first night launch in program.

April 5, 1973. Pioneer 11, Atlas-Centaur-30. Performed flyby of Jupiter and first flyby of Saturn.

May 25, 1973. Saturn IB, Skylab 2, Conrad, Kerwin, Weitz. First crew on Skylab.

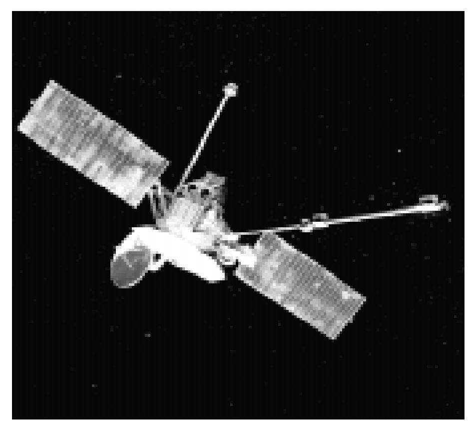
Nov. 3, 1973. Mariner 10, Atlas-Centaur-34. First flyby of Mercury. Three encounters, 1974-75.

July 15-24, 1975. Saturn IB, Apollo-Soyuz Test Project. Stafford, Slayton, Brand. First linkup between U.S. and Soviet crews in space.

Oct. 16, 1975, GOES-1, Delta 116. First weather satellite to photograph complete disk of Earth every 30 minutes from geosynchronous orbit.

Aug. 20, 1977. Voyager 2, Titan III-Centaur-7. First flybys of Uranus, Neptune and their moons.

Sept. 5, 1977. Voyager 1, Titan III-Centaur-6. Performed flybys of Jupiter and Saturn.



Mariner 10

1980s

April 12-14, 1981. STS-1, Columbia. Young, Crippen. First flight of the Space Shuttle and first flight of a reusable space transportation system.

June 18-24, 1983. STS-7, Challenger. Crippen, Hauck, Fabian, Ride, Thagard. Sally Ride becomes first American woman to fly in space.

Nov. 28 – Dec. 8, 1983. STS-9, Columbia. Young, Shaw, Garriott, Parker, Lichtenberg, Merbold. First flight of Spacelab laboratory module, provided by the European Space Agency.